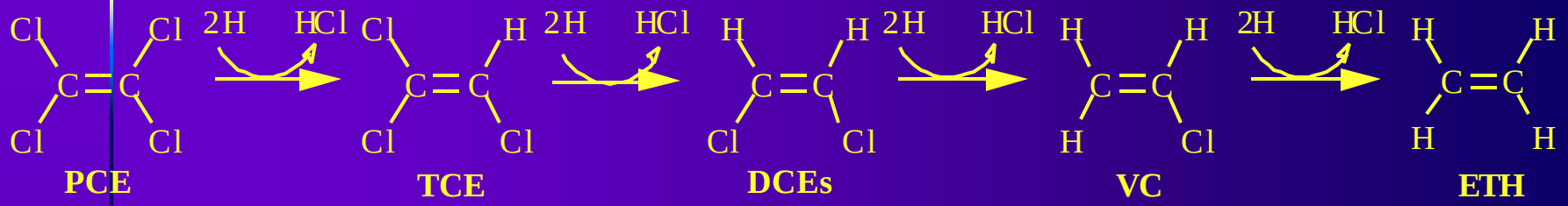
Enhanced Bioremediation of Chlorinated Solvents: Status Report

Andrea Leeson
SERDP/ESTCP
Cleanup Program Manager

Overview

- Primary focus in today's session is on anaerobic processes
- Aerobic processes are used less today, primarily due to the fact that most chlorinated solvent-contaminated aquifers are already anaerobic
- Aerobic processes are applicable to those contaminated aquifers that are aerobic

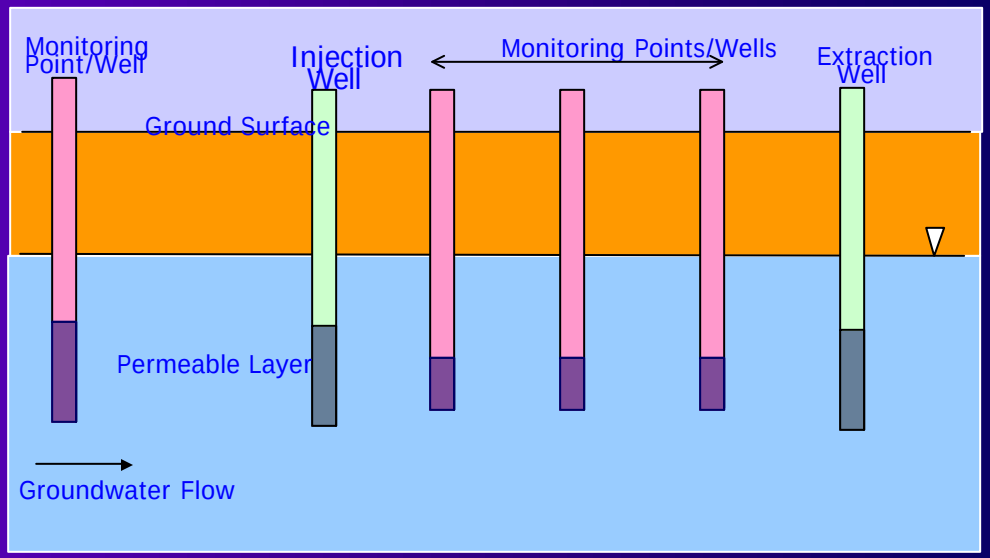
Anaerobic Reductive Dechlorination



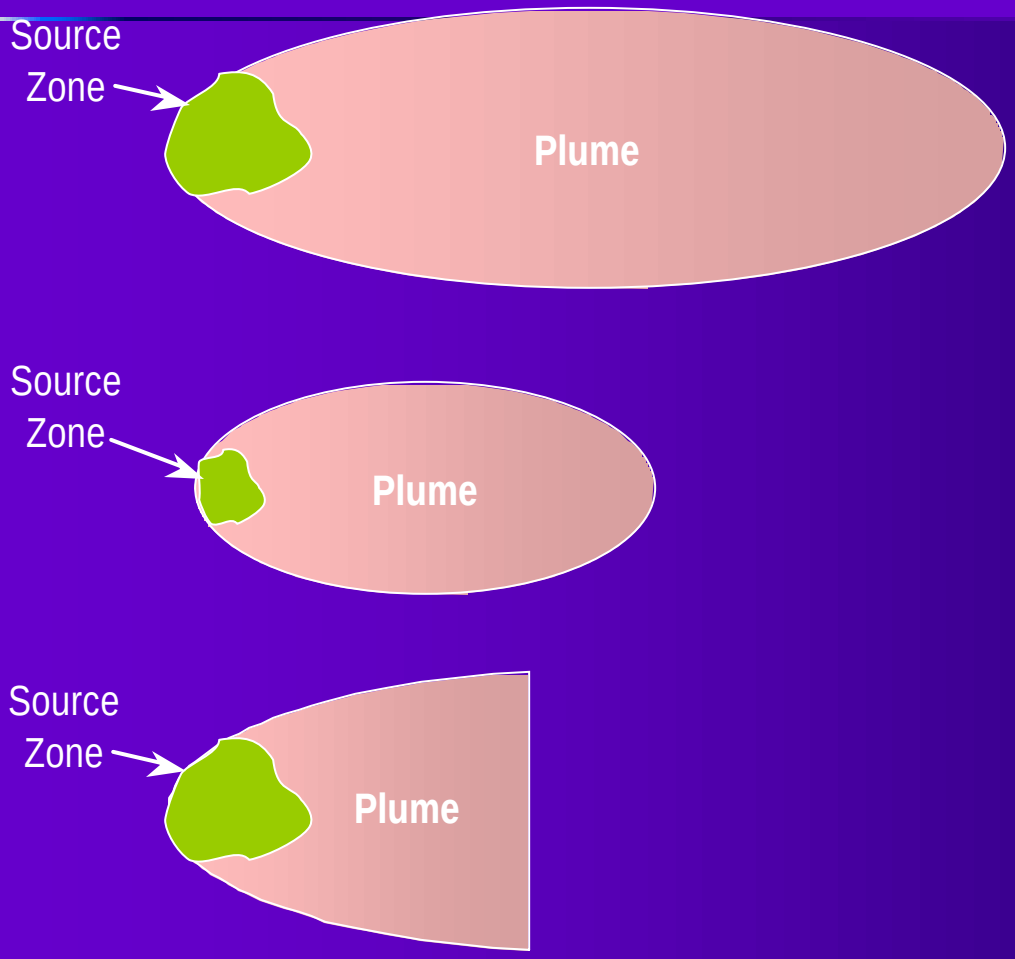
- Halorespiration or reductive dechlorination most important process for biodegradation of highly chlorinated solvents
  - Chlorinated compound used as electron acceptor, chlorine removed & replaced with hydrogen
  - Hydrogen & other compounds serve as electron donor
  - Fermentation of carbon substrates generates hydrogen

Technology Description

- Enhanced anaerobic dechlorination is an engineered process designed to deliver suitable electron donors and/or other essential nutrients to stimulate or enhance reductive dechlorination of chlorinated ethenes by microorganisms



Remedial Approaches



Scenario

Natural Attenuation

Source Zone Treatment

Plume Treatment

In Situ Delivery Techniques

- Soluble Substrates
  - Organic Fatty Acids (lactate, butyrate, acetate)
  - Molasses and refined sugars
  - Whey
- Semi-Soluble Substrates
  - HRC
  - Edible oils
- Solid Substrates
  - Chitin
  - Mulch
- Gaseous (hydrogen)

Soluble Substrates

- Typically injected directly into a source zone or plume in multiple locations
- Injection/extraction zone may be developed
- Treatability Test for In Situ Anaerobic Dechlorination
  - http://www.estcp.org/documents/techdocs/Rabit_Protocol.pdf
- Presentations today
  - Kent Sorenson (0825 & 1300)
  - Chris Lutes (1020)

Semi-Soluble & Solid Substrates (Slow Release)

- May be injected directly into a plume or are frequently used as barriers
- Sample project using vegetable oil as permeable barrier
  - http://www.serdp.org/research/CU/CU-1205.pdf
- Presentations today
  - Kent Sorenson (0825 & 1300)
  - Bruce Henry (0915)
  - Bob Borden (0940)
  - Patrick Haas (1045)

Gaseous Substrates

- Relatively new approach
- Hydrogen gas is sparged directly into contaminated area
  - http://www.serdp.org/research/CU/CU-1206.pdf
- Presentations today
  - Chuck Newell (1325)

Bioaugmentation

- Implemented at sites when:
  - Population of microbial halorespirators not present
  - Dechlorination does not proceed to completion
- Inject amendment of non-native microbes known to carry out dechlorination
  - *Dehalococcoides ethenogenes* or related *Dehalococcoides* microorganisms
  - Two approaches:
    - Inject enough inoculum to complement or replace native organisms: survive & multiply
    - Inject large quantity of inoculum to quickly degrade large amount of contaminant: long-term survival not necessary
- Presentations today: Bruce Alleman (1635)

Advantages

- Lower capital & maintenance costs
- Destruction of contaminants in situ
- Minimal disturbance of infrastructure
- Higher efficiency of mass removal
- Interphase mass transfer

Issues and Concerns

- Type of substrate
- Substrate delivery efficiency
- Design methodology
- Long Term O&M
- Specific Issues:
  - Incomplete dechlorination
  - Secondary water quality
  - Methane/hydrogen sulfide generation

How Much Carbon Do I Need?

- Probably more than you think
- Stoichiometry is not clean, 1 to 20+ lbs of C per pound of chlorinated solvent for biodegradation, more for cometabolism
- More to consume other electron acceptors: O_2, NO_2, Fe^{+3}, and SO_4
- Substantial Engineering Safety Factor, most carbon will not go into dechlorination

For Example, for a 1,000-Gallon TCE Spill

1 to 20x for Stoichiometry	10,000 to 200,000 lb
1 to 5x for Electron Acceptors	10,000 to 50,000 lb
Subtotal	20,000 to 250,000 lb
2 to 10x for Engineering Safety Factor	40,000 to 2,500,000 lb

Methodology Development

- Consistent design and operation guidance is lacking
- Current approaches:
  - Site survey report to collect data from sites on scale, substrate used, delivery approach, & cost (Bryan Harre: 0850)
  - Preparation of a Principles & Practices Manual for EAD (Ross Miller: 1415)